Discussion: Are There Material Objects in Bohm's Theory?

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1 The Issue

Bedard (1999) argues that "Bohm's interpretation is not as classical as it initially appears" (p. 223) and that, in particular, the common view that the pilot-wave theory[1] can get by with an ontology of *just* particles "do[es] not make sense" (ibid.). Indeed, "sets of Bohmian particles do not have all the intrinsic properties necessary to constitute a material object" (ibid.). This last remark is the heart of Bedard's impressive paper, the point being that the 'minimalist' interpretation of the pilot-wave theory (according to which the only entities are the particles, and their only fundamental property position) has no account of material objects.

In this note, I shall suggest that in fact the minimalist's interpretation is fully adequate. Bedard shows that the minimalist's physical world (consisting of just particles with position) is too sparse to explain why, for example,

[1]Louis de Broglie (1924) formulated essentially the same theory that Bohm (1952) did. An examination of his dissertation reveals that in fact his theory was much closer to Bohm's than is usually assumed. I have chosen, therefore, to use the 'neutral' term 'pilot-wave theory'.

a collection of particles is “a brain instead of something merely shaped [as] a brain” (ibid.). Instead, the wavefunction itself must be invoked to get any account of the forces that bind particles together. The heart of my response is just that the minimalist is not obligated to have such an account. Much of the rest of this note is aimed at making this claim plausible. I hasten to add that it is no part of my argument that the pilot-wave theory is ‘classical’, whatever that adjective may mean.

2 Review of the Arguments

Bedard presents three arguments against the minimalist interpretation of the pilot-wave theory, according to which the only ‘real’ objects are particles, and the only ‘real’ properties are positions, while the wave function does nothing more than encode the dynamics obeyed by those particles. I shall review each argument, reserving most comments for later.

Her first argument is based on the idea that “in order for a system to constitute a composite object such as a cat, table, or hammer, the right types of particles must be bonded together in an appropriate way” (p. 227). Consider two sets of particles, one ‘merely’ shaped as a hammer, the other shaped as a hammer *and* bonded together so as to maintain its shape under the stress of, for example, hitting a nail. The latter is a hammer, the former not. Bedard then points out that the pilot-wave theory may account for such ‘bonds’ by appeal to features of the wavefunction, but *not* by appeal to the intrinsic properties of the particles, of which, on the minimalist ac-

count, there is just one—position. Hence the minimalist interpretation is inadequate, for it *must* model the distinction between bonded and unbonded particles and yet cannot: "quantum mechanics would not be celebrated for successfully modeling such a distinction if the distinction were insignificant" (p. 228). (We shall see that the minimalist is not much inclined to join the celebration.)

Bedard's second argument is aimed at the idea that the configuration of particles could 'cause' our perceptions. In partiular, she considers a quantum-mechanical evolution such as:

$$|v\rangle|\text{“}v\text{”}\rangle|\text{ready}\rangle \rightarrow |v\rangle|\text{“}v\text{”}\rangle|\text{sees “}v\text{”}\rangle \tag{1}$$

where $|v\rangle$ is the state of some measured system, $|\text{“}v\text{”}\rangle$ is the state of an apparatus indicating the result "v", $|\text{ready}\rangle$ is the state of an observer not yet having observed the apparatus, and $|\text{sees “}v\text{”}\rangle$ is the state of an observer having observed the apparatus. Bedard then notes that the evolution of the particles in the observer are not functionally dependent on the positions of the apparatus' particles.

We are supposed to conclude that the apparatus' particles do not, therefore, 'cause' the perception "sees 'v'". To bolster this conclusion, Bedard further claims that on the counterfactual analysis of causation, the positions of the apparatus' particles do not affect the observer's particles, because "according to the counterfactual analysis, 'the pointer particles cause the perception' means that if the pointer configuration were different, then the

perception would have been different" (p. 231). But we should be somewhat more careful, here. Surely, for example, the counterfactual analysis says more. Consider a baseball breaking a window. Is it true that 'had the ball been elsewhere, the window would not have broken'? No. One requires that the difference be 'enough'. (E.g., 10^{-10}cm is probably not enough.) True, the configurations that *might* make a difference happen to have probability zero, if in fact the wavefunction is as Bedard describes in (1), but several problems arise here. First, is probability 0 low enough? If not, how do we evaluate the relevant counterfactual? If so, are we allowed to alter the wavefunction (in order to make these configurations to have probability greater than 0)? Such questions make it clear that appeal to the counterfactual analysis is at best problematic, and requires considerably more careful discussion. (See (Dickson, 1996) for some discussion of the difficulties for applying the counterfactual analysis to the pilot-wave theory.)

In fact, Bedard does briefly raise the possibility that the evolution is, instead,

$$\Big(|v\rangle|\text{“}v\text{”}\rangle+|w\rangle|\text{“}w\text{”}\rangle\Big)|\text{ready}\rangle \rightarrow |v\rangle|\text{“}v\text{”}\rangle|\text{sees “}v\text{”}\rangle+|w\rangle|\text{“}w\text{”}\rangle|\text{sees “}w\text{”}\rangle. \quad (2)$$

In this case, one or the other of the wavepackets for the apparatus is 'empty' (i.e., the configuration is not located there)—let it be $|\text{“}w\text{”}\rangle$. Then we might be tempted to say that if the configuration of the apparatus *had* been there, the observer *would have* seen "w" rather than "v". But then does the counterfactual analysis not entail that the configuration is causally relevant to

the state of the observer? Bedard answers 'no', for two reasons. First, "the viability of particularity [i.e., the minimal interpretation] . . . should not hinge on the complexity of the universe" (p. 232) and second, "we could construct more realistic and complex examples in which empty wavepackets exist without having the pointer particles determine which wavepacket is active or affect the brain particles' trajectories" (ibid.). The first point is crucial—I shall suggest below that in fact the only reasonable version of the minimal interpretation *should* allow that answers to 'causal' questions depend on the contingent details of this universe. The second, I do not understand, if Bedard has in mind the situation that I described schematically in (2). There, the quantum-mechanical perfect correlations between the apparatus and the observer guarantee that the observer will (with probability 1) see the result that the apparatus indicates. However, this latter point is central neither to her argument nor to mine. I shall address the general argument about 'particulate epistemology' below.

Bedard's third argument is that mere positions are insufficient to explain the correlation between our perceptions and the world. For example, colors may not depend on configuration in the appropriate way, and yet we can perceive color. In general, it is possible to perceive properties that are not in any obvious way dependent on configurations. But then configurations cannot explain our perceptions.

3 The Minimal Interpretation

Bedard quotes several authors who seem to adopt something like a 'minimalist' interpretation of the pilot-wave theory. We will do well, nonetheless, to make it clear what that interpretation says.

Bohm's formulation of the pilot-wave theory in 1952 invoked a 'quantum potential' in addition to the classical potential, and toegether they are responsible for the motions of particles—they are the potentials that appear in Hamilton's equations. Bohm seems never to have let go of the idea of the quantum potential (Bohm and Hiley, 1993). But why is it necessary? Apparently it is required to explain the 'deviation' of particles from Newtonian trajectories. For example, in the two-slit experiment, where there is no classical force acting on the particle between the slits and the screen, one 'must' invoke a 'quantum force' to explain why the particle does not follow the Newtonian trajectory. (Bohm and Hiley (1993) provide some nice pictures of these 'curved' trajectories.)

The minimalist interpretation that I would advocate (were I an advocate of the pilot-wave theory in the first place) begins by asking why we must appeal to Newton to establish 'what is expected'. Instead, why not simply continue to allow that the particle experiences no force between the slits, and yet its trajectory is not the classically expected trajectory? This idea suggests that we consider a space-time in which these non-classical yet free motions are geodesics, so that, in much the same way that we no longer

invoke the ‘force of gravity’ to explain deviations from Euclidean geodesics, so also we would not invoke the ‘quantum potential’ to explain deviations from the Newtonian trajectories. This idea has been carried out with enough rigor to render it at least a plausible foundation for an interpretation of the pilot-wave theory (Pitowsky, 1991).

The sole role for the wavefunction, then, is to determine the structure of space-time. It does not describe any other ‘real features’ of the world, and there are no ‘forces’, ‘potentials’, or anything of the sort accounting for the non-classicality of the motions of particles.

What sort of metaphysics goes with this view? It is reductionistic, in the traditional sense. A crucial part of this attitude of reductionism is that our accounts of the world—in particular, the categories that we use to describe the world and relations amongst objects in it—might not be ‘fundamental’, but might instead be imposed by us on the world. A familiar example is afforded by heat. Suppose that statistical mechanics is a successful reduction of thermodynamics, that heat is nothing more than the motion of molecules, and similarly for the other central concepts of thermodynamics. Then, where thermodynamics might lead us to refer to such things as ‘the quantity of heat’, ‘the flow of heat’, and so forth, we would, in light of this reduction, understand that these phrases do not straightforwardly refer to any real entities or properties of entities in the world.

An example familiar to philosophers is afforded by Hume’s account of causation. Causes are not in the world, according to this account; they are

‘constant conjunction with an inference by the mind’; i.e., we impose causal relations on the world, where in fact there is nothing other than constant conjunction. In general, the minimalist interpretation is open to the idea that the categories that you and I use to describe the world are not the real categories into which the things in the world actually fall—not even close. The minimalist is open to a radical revision of our ordinary discourse about the world in light of our interpretations of scientific theory.

4 Replies to Bedard’s Arguments

This feature of the minimal interpretation—and reductionism in general—makes it clear where Bedard’s arguments miss the mark. She assumes the legitimacy of certain distinctions made *by us*, and then requires that physical theory provide an explanation of, or account of, those distinctions in purely physical terms. The minimalist, however, is open to the idea that our mode of description may be largely responsible for the putative distinctions. While Bedard does implicitly acknowledge that her arguments do not apply to this reductionistic form of minimalism (I shall quote two cases below), apparently she does not sufficiently appreciate that reductionism was the only plausible form of minimalism in the first place.

Consider again the case of the real and false hammers. Bedard notes that there are no resources internal to the minimalist’s description of the world to distinguish between real and false hammers. But the minimalist need not agree that such distinctions are reflected in fundamental physical facts about

the world. As far as the world is concerned, 'merely' hammer-shaped sets of particles and 'true hammers' are no different—in much the same way that there is no physically fundamental difference between a beautiful painting and an ugly one. The sets of particles that *happen*, by virtue of their trajectories, to remain shaped as a hammer even under 'stress' (another concept imposed by us!) are picked out *by us* as special—presumably because they are useful for pounding nails.

It is crucial, now, to note that the pilot-wave theory *does* predict that, under the right conditions (that is, in a universe with the right sort of spatio-temporal structure and initial configuration—and we may have just gotten 'lucky' in this respect), there will be sets of particles that are hammer-shaped, and that will remain so under 'stress'. It is crucial, in other words, to realize that Bedard has not shown that there could be no hammers, according to the minimalist view. Her argument, rather, establishes that the minimalist view has no *explanation* of their 'hammerhood', rather than their 'hammer-shapedness'. In general, it has no *explanation*, in terms of fundamental physical facts, of the difference between 'bonded' and 'unbonded' particles. But the minimalist interpretation need provide no such explanation.

The virtue of Bedard's first argument is to highlight this fact in a particularly sharp way, and to make it clear that the minimalist must be a radical reductionist of roughly the Humean sort. But the minimalist was already committed to this view from the start—one can hardly claim that the only

truly existent objects are point particles with positions and fail to notice that such a claim involves a particularly radical form of reductionism. Some may be unsatisfied by the view, but Bedard has not shown that it "do[es] not make sense" (p. 223). To put it in her terms, Bedard *has* demonstrated "the incompatibility of particularity with theories in which certain material objects have essential properties that are causal" (p. 229), but the minimalist need acknowledge no such objects.

What I have said to this point should make it clear how to respond to Bedard's second argument as well. The point there (and let us grant it in spite of the problematic invocation of the counterfactual analysis of causation) was that configurations do not, in general, cause observers' perceptions. Again, the reductionist is not committed to the view that configurations *do* cause observers' perceptions. Indeed, the very notion of a causal conection is dispensible on this view. The minimalist interpretation *does* predict the requisite correlations. Non-reductionists understand them causally.

Bedard's third argument contains the germ of a potential problem for the minimalist. However, outside the context of some concrete theory of perception—not to mention our consciousness of perceptions—there is very little that can (or ought to be) said about the relation between the physical world and our perceptions of it. Nonetheless, the potential problem is that if this theory, 'we know not what', entails that consciousness has nothing to do with configurations, then the minimalist will have some explaining to do. One might be tempted to add that Bedard has shown that *however* our

brains physically encode information about the world, the configurations of particles in the world cannot be the causes of those encodings. Agreed, but we have already seen that the minimalist need not provide a description of such putative causal connections in physically fundamental terms (i.e., purely in terms of the positions of point particles).

5 Objection and Conclusion

One might object that the position I am describing here is just the position already examined by Bedard, namely, that the hammers are distinguished from the non-hammers not by their instantaneous properties, but by their entire histories (trajectories). She rejects this view, saying that "if an object's essential properties include causal properties, these causal properties should not be smuggled in through some of their effects (such as particle trajectories)" (p. 229). The reductionists as I have described them will, of course, reject the antecedent.

There are two ways to do so. First, the reductionist might indeed be able to reduce causal properties to properties of a trajectory, in which case causal properties are not in fact 'essential', in the same way that heat is not an essential property of ensembles of particles (let us assume). Having reduced heat to the motion of molecules, it is no good saying "if heat is an essential property, then do not smuggle it in through its effects (the motions of molecules)" for heat is not essential. Second, the reductionist might simply refuse to admit that causal properties are even reducible to

fundamental physical properties. Causal properties simply have no place at all in a physical theory. So said Hume: the property of being a hammer has two parts, 'constant hammer-shape' and 'inference by the mind'.

So what do we learn from Bedard's paper? We learn that the minimalist *must* be a reductionist. That lesson is valuable, though I have suggested that in any case there was little doubt, even prior to Bedard's paper, that the minimalist should be a reductionist. Nonetheless, Bedard has provided us a very fine illustration, in detail, of just why the minimalist must be a reductionist, and just how radical that reductionism might have to be.

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